Engineering Graphics
Concept Inventory

Sheryl Sorby
Mary Sadowski
Survey

https://tinyurl.com/EGCI-2018

Mobile device - landscape
Creating a Concept Inventory

- Brainstorming
- Delphi Study to Define Concepts
- Question Development
  - Pilot, Alpha, Beta, Gamma
- Data Analysis
  - Validity, Difficulty, Discrimination
- Discussion
Framework for Concept Inventory Development

- Cognition
  - How/what students learn
- Observation
  - Activities used on assessment
- Interpretation
  - How to understand the results
Framework for Concept Inventory Development

- **Cognition**
  - How/what students learn

- **Observation**
  - Activities used on assessment

- **Interpretation**
  - How to understand the results
Delphi - Round 0 - Brainstorming

- Galveston, Texas
- Small group of graphics professionals
- Brainstorming activity
- Identify engineering graphics topics
- Resulted in 120 topics
  - Consolidated into 80 topics
Brainstorming Concepts and Topics

Symbol Systems 3 5 5
Variability 2
GDT 2 (5,4) 3
Schematic Drawings 3 5 4
Data Representation 3 5 4
Working Drawings 3 5 4 5
Color 2 2
Shading 3 2 (3,7)
Rendering 5 2
Ruled Surfaces 2 3 2
Clearances 2
Fits 2
Assemblies 1 3
Exploded Drawings 3 5 5 3
BOM 2 5 4 5
Paper Size 2 5

Solid Geometry 3 2 2
Oblique Geometry 3 2 2
Line Precedence 5 5 3
Extrusion 3 2
Lofting 3 2
Revolution 3 2 2
Sweeping 3 2
Blending 3 2
Part History 1 7 2 5
Feature Dependency 1 7 2
Slope 2 2
Curvature 1 2 2
Tangency 1 2 2
Radius of Curvature 3 2 2
Conic Sections 3 2 2
Delphi - Round 1

- 80 topics
- 40 panelists
  - High school teachers
  - Community college instructors
  - University professors
  - Industry representatives
- 52 topics were moved forward
- 31 topics were dropped
- 6 topics were added
Delphi - Round 2

- 58 topics evaluated
- 31 expert panelists

- Topics coalesced into 12 major concepts
  - 37 constructs within the concepts

- Visualizing in 2D and 3D
- Mapping between 2D and 3D
- Object Representation – Visual Depiction
- Planar Graphical Elements
- Sectional Views
- Engineering Methodologies for Object Representation
- Projection Theory
- Parallel Projection Methodologies
- Drawing Conventions
- Dimensioning
- Solid Modeling Constructs
- Scale & Similarity
Delphi - Round 3

- 12 major concepts
  - 62 constructs within the concepts
- 31 panelists

Final results

- 10 major concepts
  - 37 constructs within the concepts

Dropped
- Scale & Similarity
- Object Representation – Visual Depiction

- Visualizing in 2D and 3D
- Mapping between 2D and 3D
- Planar Graphical Elements
- Sectional Views
- Engineering Methodologies for Object Representation
- Projection Theory
- Parallel Projection Methodologies
- Drawing Conventions
- Dimensioning
- Solid Modeling Constructs
Ranked by importance

**Visualizing in 2D (4.81)**
- Edge View
- Normal
- True Shape and True Size
- View Alignment
- View Direction

**Dimensioning (4.60)**
- Shape Description
- Size Description
- Dimension Placement
- Location Description

**Sectional Views (4.63)**
- Full Sections
- Half Sections
- Removed Sections
- Revolved Sections
- Offset Sections
- Aligned Sections

**Drawing Conventions (4.50)**
- Annotations and Notes
- Callouts

**Planar Graphical (4.48)**
- Reference Planes
- Cutting Planes
- Datum Planes
- Projection Planes
Ranked by importance

**Projection Theory (4.47)**
- Line of Sight
- Plane of Projection
- Auxiliary Views
- True Length
- Edge View
- Inclined Surfaces

**Mapping between 2D and 3D (4.45)**
- Interpretation
- Creation

**Engineering Methodologies for Object Representation (4.29)**
- Isometric
- Exploded
- Assembly

**Parallel Projection Methodologies (4.27)**
- Orthogonal
- Isometric

**Solid Modeling Constructs (4.27)**
- Extruding
- Sweeping
- Revolving
- Features
Post Delphi Survey

Graphics Instructors were asked to rate the difficulty a typical student might have understanding each of these concepts.

Likert Scale: 1 least difficult  ➚ 5 most difficult

Distribution

Engineering Design Graphics MidYear Meeting
Delphi Panelists
EDGD listserv

Participants: 80
## Survey Results

Concept Map

(Note, some concepts were dropped or consolidated during the course of the project)
Framework

- Cognition
  - How/what students learn
- Observation
  - Activities used on assessment
- Interpretation
  - How to understand the results
Open-Ended Questions for Pilot Study

- Based on the 10 original topics from the Delphi study, 60 open ended questions were created
  - Multiple members of the research team contributed to the creation of these questions and drew from their personal experience in teaching graphics courses
  - Sample questions are shown on the following slides
Open-Ended Question Example

Indicate the location of Surface A in the top and side views.
Open-Ended Question Example

Given the two views, draw the appropriate third view of the object.
Open-Ended Question Example

Given the three complete views, sketch an isometric view of the given object.
Open-Ended Question Example

Draw the cutting plane line, in the proper view, that would result in the section view shown in the front view below.

![Diagram of cutting plane line and section view](image)
Open-Ended Question Example

Add generic dimensions without values to fully define the object.
Pilot Study

- The 60 open ended questions were piloted with over 900 students at 3 universities
  - Due to time constraints and the number of questions, not every participant was given every question, but each question had at least 15 responses
    - Along with answering the questions, students were also asked to rate each question using a Likert scale indicating how well they understood what the question was asking, and how they rated its difficulty
- Now you’ll be given a copy of some of these sample questions and we will take a few minutes for you to sketch your answers
Incorrect Student Answer

Label Surface A in the top and side views.

SolidWorks Student Edition. For Academic Use Only.

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Incorrect Student Answer

Given the two views, draw the appropriate third view of the object.

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**SolidWorks Student Edition**
For Academic Use Only.

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Incorrect Student Answer

Given the three complete views, sketch an isometric view of the given object.
Incorrect Student Answer

Draw the cutting plane line, in the proper view, that would result in the section view shown in the front view below.

SECTION A-A

I understood what the question was asking: Strongly Agree —— Strongly Disagree

I feel that the question was: Very Easy —— Very Difficult

SolidWorks Student Edition. For Academic Use Only.
Incorrect Student Answer

Sketch the auxiliary view of the inclined surface of the object shown below.
Incorrect Student Answer

Add dimensions without values to fully define the object.
Distractor Generation

- Pilot responses from all institutions were collected and the results aggregated
- The team individually wrote potential distractors for each item using the open-ended student responses as a guide
- Then as a full group, selected the three most appropriate distractors
  - Final items are multiple choice with 4 possible answers so three distractors are needed per item
- The selected distractors were typically similar to the most prevalent incorrect coded responses from the pilot study
  - Most distractors have only one thing incorrect
Alpha Version

- First test of the items with the newly generated distractors, administered in Fall 2015
  - There were 3 editions of the EGCI with 25 items each
  - 4 universities and over 1000 students participated

- Results were analyzed
  - Items were rated by difficulty and discrimination
    - Items for the Beta version were chosen to have questions in various levels of difficulty that met minimum discrimination criteria
  - The curriculum at the participating institutions was discussed to see if some of the frequently missed questions from a given institution were on topics not covered in their curriculum
Beta Version

- Two different versions of the CI were created for the Beta test that was administered in Spring 2016
  - These two versions had nearly equal discrimination and equal average difficulty
  - The team made sure that there were questions that addressed every concept on the concept map
- Over 1000 students at 4 universities participated
Gamma Version

- The Gamma version was administered in Spring 2017
  - There was one version with 30 questions
    - 4 on dimensioning
    - 3 on planar geometry
    - 8 on projection theory
    - 5 on sectional views
    - 10 on mapping between 2D and 3D
  - Over 1000 students at 4 universities participated
Item #: 0009

Select the set of views where Surface A is labeled correctly.

A. 

B. 

C. 

D.
Gamma Version Sample Graphics

Item #: 0047.4

Given the front and right views of the object, select the option that shows a correct top view.

?  

A.  B.  C.  D.
Item #: 0006

Given the front, side, and top views of the object, select the option that shows the correct isometric view.

A.  
B.  
C.  
D.  
Gamma Version Sample Graphics

Item #: 0021

Select the option that shows the correct cutting plane that produces Section A-A.
Item #: 0001

Given the orthographic views, select the option that shows the correct auxiliary view.

[Diagram with orthographic views and options A, B, C, D]
Gamma Version Sample Graphics

Item #: 0017

Select the correctly dimensioned object from the object given below.

A.

B.

C.

D.
Validity Study

- Extent to which measurement supports interpretations
- Several forms
- Face Validity
  - Type of Content Validity
  - Appears to measure what it is purported to
- Solicit group of expert opinions
  - Agree/disagree with items and concept pairing
Session ETD 415

The above question is intended to measure the concept of:

SECTIONAL VIEWS.

Do you agree that this is what it measures?

YES ☐ NO ☐

Which concept should this instrument measure?

☐ MAPPING BETWEEN 2D AND 3D
☐ PARALLEL PROJECTION METHODOLOGIES
☐ PLANAR GEOMETRY
☐ OTHER (please indicate): __________

☐ PROJECTION THEORY
☐ SECTIONAL VIEWS
☐ DIMENSIONING

The above question is intended to measure the concept of:

SECTIONAL VIEWS.

Do you agree that this is what it measures?

YES ☐ NO ☐

Which concept should this instrument measure?

☐ MAPPING BETWEEN 2D AND 3D
☐ PARALLEL PROJECTION METHODOLOGIES
☐ PLANAR GEOMETRY
☐ OTHER (please indicate): __________

☐ PROJECTION THEORY
☐ SECTIONAL VIEWS
☐ DIMENSIONING

☐ CAD CONCEPTS
Framework

- Looked at existing instruments
- Cognition
  - How/what students learn
- Observation
  - Activities used on assessment
- Interpretation
  - How to understand the results
Psychometrics

- **Item Difficulty**
  - “Easiness” of an item

- **Discrimination Index**
  - Item’s ability to differentiate a high- and low-performing students

- Use BOTH concurrently to identify items
# Item Difficulty Level: Definition

The percentage of students who answered the item correctly.

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<th>High (Difficult)</th>
<th>Medium (Moderate)</th>
<th>Low (Easy)</th>
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<td>&lt;= 30%</td>
<td>&gt; 30% AND &lt; 80%</td>
<td>&gt;=80%</td>
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Oosterhof, A. (1990). *Classroom Applications of Educational Measurements*. Merrill, Columbus, OH.
Item Difficulty Level: Discussion

- Is a test that nobody failed too easy?
- Is a test on which nobody got 100% too difficult?
- Should items that are “too easy” or “too difficult” be thrown out?
What is Item Discrimination?

- Generally, students who did well on the exam should select the correct answer to any given item on the exam.
- The **Discrimination Index** distinguishes for each item between the performance of students who did well on the exam and students who did poorly.
How does it work?

- For each item, subtract the number of students in the lower group who answered correctly from the number of students in the upper group who answered correctly.
- Divide the result by the number of students in one group.
- The Discrimination Index is listed in decimal format and ranges between -1 and 1.
Item Discrimination: Discussion

- What factors could contribute to low item discrimination between the two groups of students?
- What is a likely cause for a negative discrimination index?
### Item Statistics from Alpha Version

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Item - Difficulty vs. Discrimination

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Sections  Projection Theory  Planar Geometry  Mapping BT 2D and 3D  Dimensioning

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Interpretation of score

How to make sense of it?

Common examples

- SAT
  - 0-1600, Math and Verbal

- BMI
  - ratio between weight and height-squared

- PSVT:R
  - 0-30, all points the same

- EGCI
  - 0-30…all scores the same?
## Concepts on Instrument

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Sample Scores from EGCI

- **Current version**
  - 30 (10-10-10)
    - 2D to 3D
    - Parallel Projection & Planar Geometry
    - Conventions

- **Today’s version**
  - 9 (3-3-3)
    - Same breakdown

- **Important for intended use!**
Example Scores Distribution

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...if we look closer

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- Total Score
- Sub-scores

- Assessment vs. Evaluation of scores
Item #: 0027

Select the option that shows all the standard views of the object correctly aligned in orthographic projection.

A.

B.

C.

D.
Future Plans with the EGCI

- Recent completion of final instrument
- Additional statistical analysis
- Dissemination of instrument
  - Use of instrument
  - Process of creating educational assessment instruments
- Linked from EDGD website
Acknowledgement and Contact

- Support of the National Science Foundation for this project through collaborative grants DUE-1432280 and DUE-1432288.

- Dr. Mary Sadowski
  - sadowski@purdue.edu

- Dr. Sheryl Sorby
  - sorbysa@ucmail.uc.edu